# ISRO SATELLITE MISSION SUPPORT FACILITIES: SCOPE AND FUTURE PLANS

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## 1. INTRODUCTION

The Indian space programme is working to develop and apply space technology and space sciences for the socioeconomic benefit of the nation. The major thrust of the Indian Space Research Organization (ISRO) is to provide communication and education to widely dispersed rural communities, and to survey and manage the country's natural resources through the cost-effectiveness and special advantages of satellite technology. India also maintains a modest scientific research programme which employs satellite programs.

ISRO's satellite missions are supported by a medium-sized ground network which is continuously being upgraded to meet the rising volume and complexity of the demand resulting from successive programs. Increased network support requirements for certain mission phases are met through international cooperation. This paper provides a brief overview of the Indian space program; discusses the network's present capabilities for satellite data acquisition, tracking mission control, and data dissemination; and describes plans for these areas in the decade ahead.

## 2. THE INDIAN SPACE PROGRAM

### (a) Satellites in orbit

During the period 1975-1980 India launched three satellites: Aryabhata, Bhaskara and Rohini.

Aryabhata was primarily a technological satellite from which we hoped to gain experience in satellite construction; the satellite also carried three scientific experiments. Aryabhata was launched into near-circular, 600 km altitude orbit on April 19, 1975 by a Soviet rocket through the cooperation of Intercosmos Council of the USSR Academy of Sciences. Designed for a six-month lifetime, all the technological systems continue to function, although the scientific experiments had to be terminated five days after launch due to a power regulator failure.

Bhaskara, the experimental remote sensing mission, was launched into a 525 km near-circular orbit on June 7, 1979, again with Intercosmos cooperation. Designated the Satellite for Earth Observations (SEO), Bhaskara carried television cameras and passive microwave radiometers for remote sensing data throughout its two years lifetime. The mission has now been terminated due to the depletion of fuel for attitude control.

Rohini was placed into a 300 by 900 km elliptical orbit by the Indian Satellite Launch Vehicle SLV-3 on July 18, 1980. The satellite carried technological systems for launch vehicle evaluation.

### (b) Recent Missions

Three satellites were launched in 1981: the RS-D-1, APPLE, and SEO-II.

RS-D-1 was placed in a near earth elliptical orbit by the first developmental flight of the SLV-3 vehicle. It carried a sensor for panchromatic landmark mapping using a linear photo-diode array scanner.

APPLE (Ariane Passenger Payload Experiment) is an experimental, geostationary communications satellite, launched with Meteosat-2 in June 1981 in the third developmental flight of ESA's Ariane launch vehicle.

SEO-II is an improved version of Bhaskara, launched in the last quarter of 1981 on an Intercosmos launcher.

### (c) Operational Domestic Satellite System

Ford Aerospace and Communications Corporation of the USA is building two geostationary multipurpose satellites named INSAT-1A and INSAT-1B under a contract with the Government of India. Each satellite has a 7-year design life, 12 transponders in the 6/4 GHz band each having 1200 voice/data channels and a two-channel TV capacity. With a network of 35 ground stations, they will provide direct TV broadcasts to low-cost community receivers. The INSATs will also carry a two-channel Very High Resolution Radiometer providing half-hourly earth-disc imagery to the Meteorological Data Utilization Center (MDUC) at New Delhi. Up to 800 unmanned land and ocean-based data collection platforms will relay meteorological, hydrological, and oceanographic data through INSAT to MDUC. INSAT-1A is due for launch in early 1982, and INSAT-1B will be launched a year later. The INSAT series will be continued with Indian-built satellites, the first of such planned for the middle of the decade.

(d) Scientific and Technological Satellites

Satellites of the **40-50** kg class, carrying scientific and technological experiments, are planned for the **1981-84** developmental and operational flights of the SLV-3 vehicle. The augmented SLV (ASLV) vehicle, which is under development, will launch **150** kg class satellites with scientific and technological payloads.

(e) Remote Sensing Missions

IRS-1 (Indian Remote Sensing Satellite) with high-resolution multispectral remote sensing payloads is scheduled for launch in **1984**. IRS-1 will be of the semi-operational class and will be placed in sun-synchronous orbit; thereafter, operational remote sensing missions will continue to be launched on the Polar SLV (PSLV).

## 3. THE ISRO/DOS GROUND SUPPORT FACILITIES

The ISRO/DOS ground support facilities are organized as follows:

(a) ISRO Telemetry Tracking and Communications Network (ISTRAC) consisting of the telemetry, tracking and telecommanding ground stations; communications network; spacecraft control centre; network control centre; and data processing facility.

(b) Earth stations working in the C-band and providing communications experiments, telemetry acquisition, and the tracking of C-band communications satellites.

(c) The INSAT-1 Master Control Facility, set up exclusively to service the INSAT-1 Satellite.

(d) The Indian Landsat Earth Station at Hyderabad.

Figure 1 shows the location and general capabilities of the major ground installations.

(a) The ISTRAC Facilities

The ISRO Telemetry, Tracking, Command and Communications (ISTRAC) network was set up in **1976** to provide a nationwide network of multifunction ground stations and associated facilities. ISTRAC plans, executes, and manages the ground facilities to support India's increasingly complex space programmes. ISTRAC provides complete ground support for all the Indian satellite missions, and is responsible for the routine mission operations of spacecraft.

ISTRAC has its central office at SHAR Centre, Sriharikota, and operates

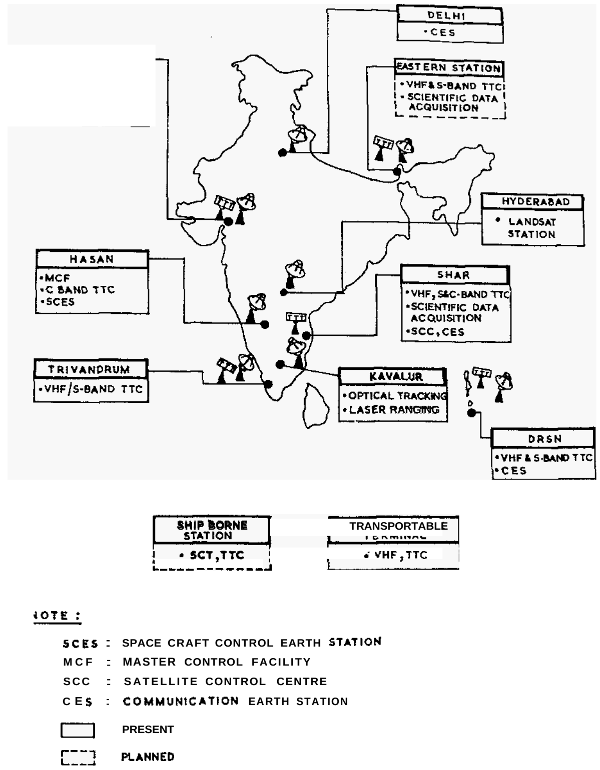


Fig. 1: ISRO/DOS Ground Facilities

ground stations at SHAR, Ahmedabad, Carnicobar, and Trivandrum, in addition to a transportable ground station with optical and laser tracking facilities at Kavalur.

ISTRAC Ground Stations. The SHAR Ground Station at Sriharikota was commissioned in **1975** for the Aryabhata Mission and has been upgraded through successive space programs. Presently, SHAR is the maximally equipped station of the network, providing two independent transmitting antennae, C-band telemetry reception, and facilities for both analog and digital data recording on magnetic tapes. Limited, mission-independent, quick-look facilities are also located at the station. The SHAR ground station has a GRARR compatible VHF tone range system and one-way doppler and interferometry in the **136-138** MHz band.

The Ahmedabad ground station was commissioned in **1979** and has one VHF antenna, three diversity combined receiver chains, three PCM decommutation chains, one telecommand chain, and a tone range system. The station has limited quick-look display hardware and works in conjunction with the Ahmedabad Earth Station for C-band telemetry and ranging.

The Down Range Station (DRSN) a+ Carnicobar was commissioned in **1979** to provide both telemetry and tracking

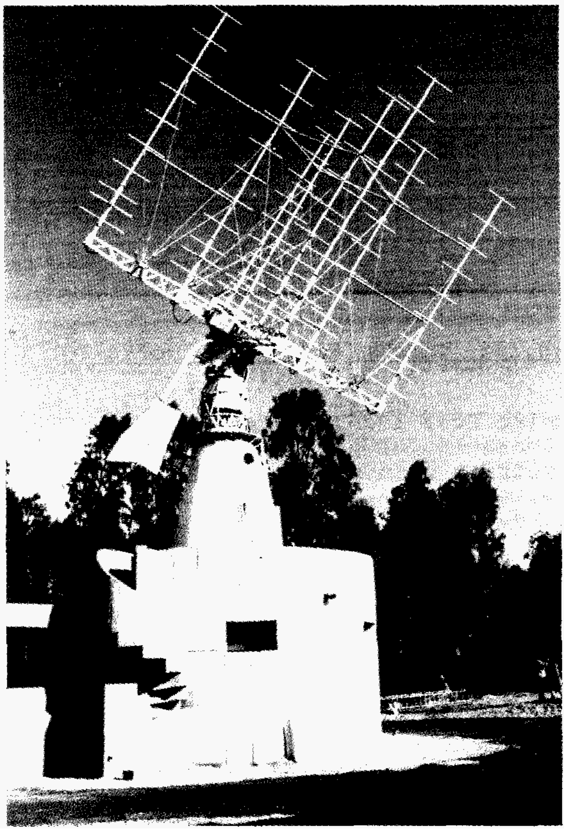

Fig. 2: Telemetry Antenna at SHAR

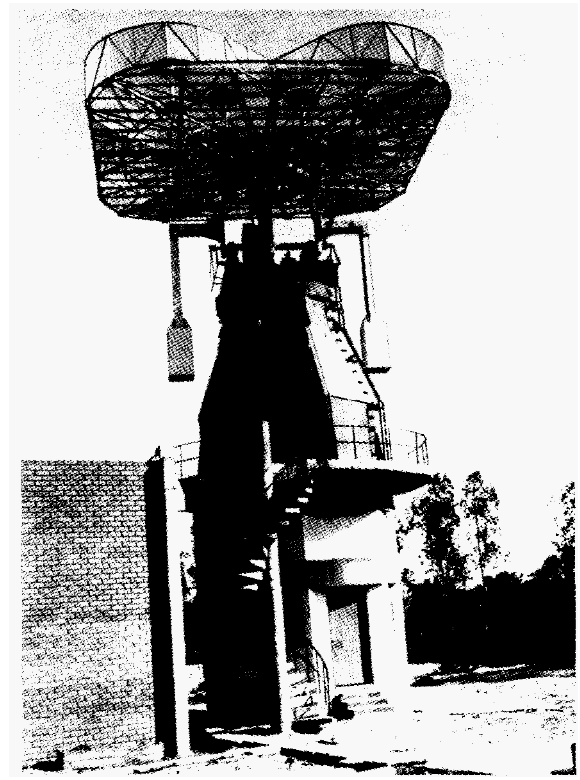

Fig. 3: Telecommand Antenna at SHAR

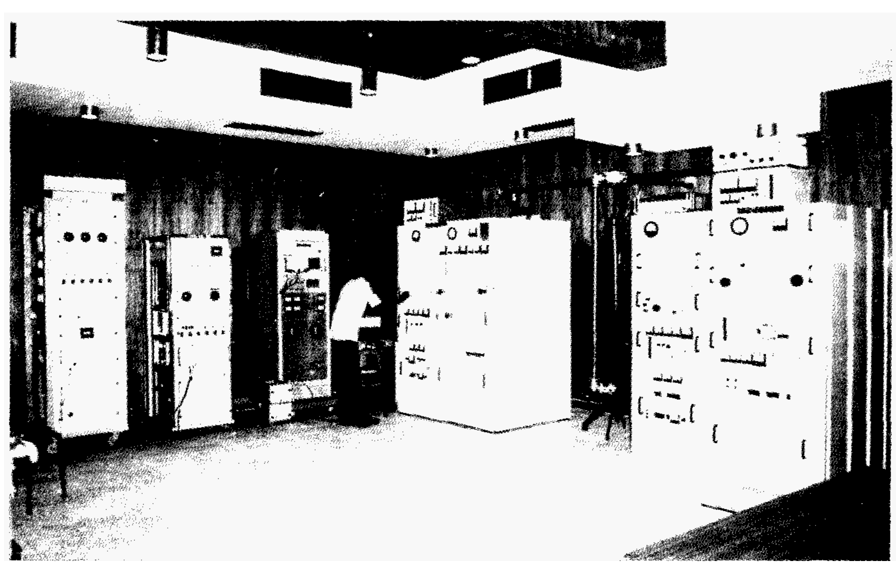

Fig. 4: VHF Transmitter, SHAR

support to the upper stages of launch vehicles, and also early orbit phase support to satellites. It has one telemetry receive chain, one PCM decommutation chain, a telecommand chain, a VHF tone range system, and S-band range rate and angle measurement.

The Trivandrum ground tation is located at the Thumba Equatorial Rocket Launching Station and has only VHF telemetry reception capability. It is used primarily for early orbit phase support of SLV launched satellites.

The Transportable Ground Station is trailer-based and was commissioned in 1981 for the APPLE Mission. It provides one chain each of VHF telemetry and telecommand. It was installed at Fiji for the early orbit phase support of the APPLE Mission, and will be relocated as future program needs dictate.

The characteristics of the ISTRAC ground stations are summarized in Table I.

Optical Tracking and Laser Ranging. The ISRO Satellite Tracking and Ranging Station (STARS) located at Kavalur, altitute 800 meters, provides optical tracking and laser ranging facilities. The facility has been established with the cooperation of Intercosmos, USSR. The technical features of the STARS facility are summarized in Table 11.

Telecommunications Network. The communications network interconnects the ISTRAC ground stations and the Satellite Control Centre, SHAR. A dedicated 50-band duplex teleprinter and 1200-band voice/data link are available between the Control Centre and Ahmedabad stations. Ahmedabad and SHAR are also connected by teleprinters to the ISRO Satellite Centre at Bangalore. DRSN is connected to the control centre through dedicated HF radio telephone and HF teleprinter service, while dedicated teleprinter and voice/data links connect the transportable ground station to the Control Centre during the support periods. The Trivandrum ground station is connected only by teleprinter during its support period.

During the early orbit phase of satellite missions it has been necessary to augment the ISTRAC network through external support. The Bhaskara mission was supported by Bears Lake, USSR, and CNES stations at Toulouse, Kourou, and Pretoria. Dedicated teleprinter links were established with Intercosmos and CNES for the first few weeks of the mission. APPLE will be supported by the Xourou and Carnarvon stations of ESA.

Figure 5 shows the communication network that has been established for supporting the early orbit phase of APPLE. Communication links are established by the

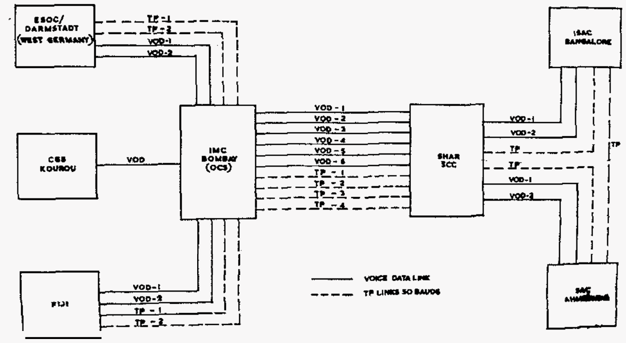


Fig. 5: Communications Networks For The Apple Mission

Indian Post and Telegraph Department with cooperation of its counterparts in other countries when necessary. Equipment for routine line quality tests are provided at the network control centre at SHAR.

The Satellite Control Centre. The multi-mission Satellite Control Centre (SCC) was established at SHAR to provide spacecraft and network monitoring and control and mission support data processing. The network stations operate in the manual mode either under real time voice command from the Control Centre or under schedules sent through the teleprinter; telemetry data flows to SCC through the data links. Presently, the SCC can acquire up to four independent simultaneous telemetry data streams and display any two streams on five interactive CRT/ANK terminals in any combination. Two of the terminals have hard copy facilities, while the two other data streams can be logged on digital magnetic tapes. Spacecraft parameters are processed in real time and displayed in the form of preformatted CRT pages to suit the flight operations. The displays feature engineering conversion, limit checking, alarm service, command verification, and spacecraft status change flagging. Modular routines can display the fuel budget, power budget, or any set of telemetry words or full telemetry frames on the CRT/ANK terminals.

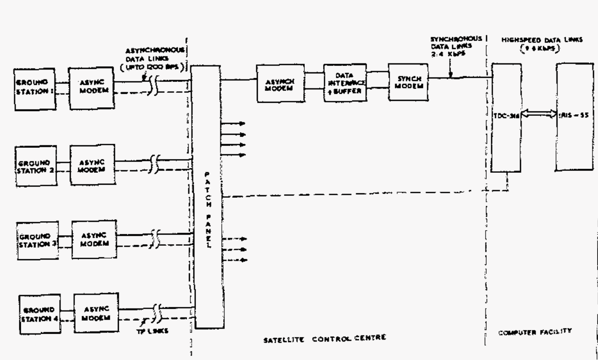


Fig. 6: Network And Data Processing Configuration

TABLE 1

Features of ISTRAC Ground Stations

| Parameter | SHAR Ground station | Ahmedabad Ground Station | Down Range Station | Trivandrum Ground Station | Transportable Station |
|---|---|---|---|---|---|
| LOCATION | | | | | |
| - Longitude | 80° 11' E | 72° 30' | 92° 48' | 76° 52' | - |
| - Latitude | 13° 40' N | 23° 01' | 9° 9' | 8° 31' | - |
| TELEMETRY | | | | | |
| - Frequency | 136-138 MHz | 136-138 MHz | 136-138 MHz | 136-138 MHz | 136-138 MHz |
| - Antenna gain | 22 dB | 23 dB | 23 dB | 13 dB | 19 dB |
| - Polarization | Linear V&H | Linear V&H | Linear V&H | Linear V&H | Linear V&H RCP LCP |
| - Receiver noise figure | 3.0 dB | 3.0 dB | 2.5 dB | 5.5 dB | 2.5 dB |
| - Sensitivity | -135 dBm | -135 dBm | -135 dBm | -135 dBm | -135 dBm |
| - Demodulation | PM PSK FM | PM PSK FM | PM FM | PM FM | PM FM |
| - Decommutation | IRIG 1 Hz to 1 Mbps | IRIG 10 Hz to 1 Mbps | IRIG 10 HZ to 1 Mbps | - | - |
| - No. of chains | 3 | 3 | 1 | - | - |
| TELECOMMAND | | | | | |
| - Frequency | 148-150 MHz | 148-150 MHz | 148-150 MHz | 148-150 MHz | 148-150 MHz |
| - Antenna Gain | 22 dB | 22 dB | 16 dB | 13 dB | 19 dB |
| - Polarization | Linear | Linear RCP LCP | Linear RCP LCP | Linear RCP | Linear RCP LCP |
| - Transmitter Power | 3Kw | 3Kw | 1 KW | 200 W | 3 KW |
| - Modulation | AM/PM | AM/PM | AM/PM | AM/ | AM/PM |
| TRACKING | | | | | |
| - Frequency | VHF | VHF | VHF, S-band | - | - |
| - Tone Ranging Accuracy | 150 m | 150 m | 150 m | - | - |
| - Doppler | ±7 m/sec | - | ±6 m/sec | - | - |
| - Interferometer | 6 minutes | - | - | - | - |
| - Angle | - | - | 0.2 deg | - | - |
| RECORDING & DISPLAY | | | | | |
| - Analog Mag. Tape Rec. | 3 | 2 | 2 | 2 | 2 |
| - U V Recorders | 1 | 1 | 1 | - | - |
| - Digital Printers | 2 | 1 | - | - | - |
| - Display | CRT Local | BCD Local | BCD Local | BCD Local | CRT Local |
| - Timing | 10 m sec NASA, IRIG-B | 10 m sec NASA, IRIG-B | 10 m sec NASA, IRIG-B | 10 m sec NASA, IRIG-B | 10 m sec NASA, IRIG-B |

TABLE 2

Features of the Optical Tracking and
Laser Ranging Facility

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LOCATION

| | | |
|---|---|---|
| Latitude | : | 12°34' N |
| Longitude | : | 78°52' E |
| Altitude | : | 800 M above MSL |

EQUIPMENT:

AFU-75 Steller Camera

| | | |
|---|---|---|
| Aperture | : | 210 mm |
| Focal length | : | 737 mm |
| F.O.V. | : | 14° x 10° |
| Effective aperture | : | F/3.5 |
| Film size | : | 210 mm x 190 mm |
| Tracking capability | : | Satellites upto 10th magnitude, 1 m sec time accuracy. |
| Accuracy of direction | : | 1 - 2 arc seconds |
| Tracking | | Manual 4 axis |
| Guiding telescope | | F.O.V. 6° x 3° and magnification 8 and 20. |

Lader Radar (INTERKOSMOS)

| | | |
|---|---|---|
| Type | | Ruby Laser, Q Switched operation |
| Wave length | | 694.3 |
| Tracking | | Visual/manual, 10 magnitude |
| Transmit pulse duration | : | 10 n.sec |
| Pulse repetition rate | : | 60/min |
| Beam width | | 3 m rad. |
| Output energy | : | 1 |
| Power output | : | 100 MW |
| Receive aperture | : | 32 cn |
| Bandwidth | : | 20 AU |
| Guiding telescope | : | for 1° 30' |
| Mount | : | 4 axis |
| Ranging accuracy | : | 1 meter |
| Maximum range | : | 4000 KM |

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Comprehensive spacecraft checkout is carried out in near real time (NRT) and the output printed on a remote printer located in the SCC. The software for RT and NRT processing is presently mission-specific. Two microprocessor-based PCM decommutation systems, with CRT display of quick look data and hard copy facilities, have a stand-alone capability for monitoring the spacecraft.

Network status received by teleprinter is manually entered on a wall display in the SCC. A four-channel intercom system connects the consoles with the SHAR ground station. A 22-channel voice recorder is used for voice and low-speed data recording at the SCC. The SCC characteristics are summarized in Table 3.

Computer support for the control centre is provided by the SHAR Computer Facilities, the technical features of which are shown in Table 4. The computer facility provides for real-time SCC displays, near-real-time spacecraft health monitoring, altitude and orbit determination, maneuver planning, computation of satellite ephemerides, data preprocessing for delivery to end users, and other mission support computations. The support configuration for APPLE is illustrated in Figure 7.

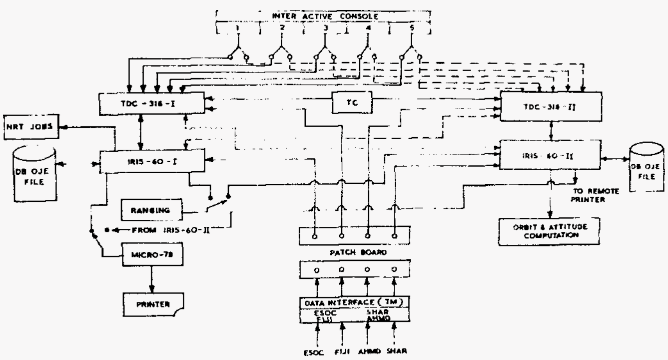


Fig. 7: Computer Configuration for the APPLE Mission

Large-volume data are mailed in the form of analog magnetic tapes by the network stations for digitization at the SHAR station. The digitized data are merged with attitude, orbit, and other re-relevant data at the computer facility and mailed as CCT to future users. Near-real-time spacecraft monitoring results are generated in the form of 5-level punched paper tapes and distributed to end users through teleprinters.

(b) Earth Station Facilities

An Experimental Satellite Communication Earth Station (ESCES) was set up in 1967 at Ahmedabad with UNDP assistance; its purpose was to give experience in satellite communications and tracking. ESCES was modified, augmented, and re-designated the Ahmedabad Earth Station. A second Earth Station was set up at Delhi in 1975. The two Earth Stations participated both in the Satellite Instructional Television Experiment (SITE) using ATS-6 in 1975 and also in the Satellite Telecommunication Experiments Project (STEP), using the Symphonie satellite, during 1977-79. These stations were used for various communication and TV broadcast/distribution experiments in the C-band; range and range rate measurements were made using the payload transponder during the SITE programme with ATS equipment.

The Ahmedabad and Delhi Earth Stations provide the ground facilities for conducting C-band communications experiments with the APPLE spacecraft. Ahmedabad Earth Station provides C-band telemetry support during the geostationary phase of APPLE mission; it also contains an S-band data receiving facility €or the reception of meteorological data from satellites. A transportable Remote Area Communications Terminal (TRACT) was commissioned in 1976 to provide TV transmission and reception, and to conduct telecommunications experiments. Table 5 summarizes the technical features of the C-band earth stations.

(c) The INSAT-1 Master Control Facility

This facility at Hassan supports the INSAT-1 satellites. The INSAT-1 SCC is operator-controlled but works in a semi-automatic mode with manual backup for command selection, initiation, and verification. The control console has multiple CRT/ANK terminals, providing computer access for real-time operations control, as well as satellite and ground equipment monitoring.

(d) The Indian Landsat Earth Station

The Indian Landsat Earth Station (ILES), located near Hyderabad, collects and processes Landsat and TIROS-N (meteorological) satellite data on an operational basis. ILES has a 10-m parabolic antenna, with G/T at 5° elevation of 21 dB °K at 2.2-23 GHz, and 15 dB/°K at 1.65 - 1.75 GHz. The antenna drive features a velocity and acceleration of 22°/sec and 10°/sec$^2$ in azimuth and 5°/sec and 1°/sec$^2$ in elevation respectively. Manual rate, auto track, rate memory, and sector scan modes are possible. 70 mm quick-look, 241 mm fully corrected film, and computer compatible

TABLE 3

Features of Satellite Operation Control Centre

| Function | Provision | Specifications |
|---|---|---|
| Computer driven display | | |
| - CRT with keyboard for real time monitoring. | 5 | Size 12" diogonal, character 7 x 9 dot matrix, display format 80 x 24, refresh rate 50 Hz, Edit, Cursor control facility. |
| - CRT without key board | 2 | Size 12" diagonal, character 7 x 9 dot matrix, display format 80 X 24. |
| - Wall display | 1 | |
| Hard copy devices: | | |
| - CRT driven digital printer | 2 | Speed 180 cps, character 7x7 dot matrix. |
| - Strip chart recorder | 1 | No.of channels:8, recording speed 1,5, 25, 50 mm/sec., type pressure sensitive paper recording. |
| Timing: | | |
| TCG/TCR | | NASA 36 format 1 KHz. Modulated code; Input 1 MHz sine curve from quartz standard; Output:1, 10,100 & 1000 pps preset to diff. time. |
| Wall displays | 2 | |
| Console displays | 8 | |
| Count down display | 1 | |
| Intercom with 12 positions | 1 | No,of channel groups 4 & page; Power output 2.5 W(each position) |
| Consoles | 10 | Space craft contrd,mission contro network control, subsystem monitoring, communication control. |
| Communication recorder | 1 | 20 channel, automatic change-over to built in standby |
| Status display | 2 | ground station status, project display. |
| Simulation equipment | 1 set | A 7 track instrument tape recorder for playing simulation tape. |

## TABLE 4

### Features of Computer Facility

| Parameters | Mini computers | Large systems |
|---|---|---|
| Computer type | TDC - 316 | IRIS- 60 |
| Number | 2 | 2 |
| Specifications | | |
| - Memory | 64 K bytes | 384 K bytes |
| - Cycle time | 1 μ sec | 700 n sec. |
| - word length | 16 bits | 32 bits |
| - Address | Byte and word addressable | Byte and word addressable |
| - Floating point processor | Single precision | Double precision |
| - Instrumtion set | 84 | 120 |
| - Communication sub-systems | One synchronous communication sub system for 16 full. duplex channels with modem interfaces. One asynchronous communication subsystem with 8 channels. | Synchronous communication sub-system with 8 channels. |
| - *Bus* structure | - One DMA bus for fast peripherals<br>- One multiplexer bus for slow peripherals | - 2 selector channels for fnst Peripherals.<br>- 2 multiplexer channels for slow peripherals. |
| Peripherals (for each system) | - Mag. tape units-4, disc unit-1 Line printer-1, Card reader-1, TTY-1, HSP Unit-1 set. | Discs-3, Mag. tapes-4, Line Printer-1 Card reader-I, TTY-1, Plotter-1 |
| Functions: | - TM quick look processing display<br>- CRT displays<br>- Communication processor | -Orbit and attitude computation<br>-target designation for ground station antennas.<br>-Scientific data analysis |

## TABLE 5

### Features of the Communication Earth Station

| Parameter | AES | DES | TRACT |
|---|---|---|---|
| Antenna | 14 m Cassegrain | 10.7 m Cassegrain | 6.1m Cassegr |
| Coverage | Az ±270°<br>El. 0 to 90° | X= 0 to 90°<br>Y= 60° total | X= 20 to 90°<br>Y= ±10° |
| Polarisation | Linear | Linear | Linear |
| Frequency band<br>-Transmit<br>-Receive | <br>5925-6425 MHz<br>3700-4200 MHz | <br>5925-6425MHz<br>3700-4200MHz | <br>5925-6425 MH<br>3700-4200 MH |
| Receive noise temp. | 55° | 55° | 90°K |
| Receive G/T | 31.7 db/°K | 28.5 dB/°K | 24 dB/°K |
| Transmit EIRP | 85 dBw (max) | 85 dBW(max) | 77 dBw (max) |
| IF | 70 ±18 MHz | 70 ±18 MHz | 70 ±18 MHz |
| Modulation | FM | FM | FM |
| LO Stability | 1 x $10^{-7}$/day | 1 x $10^{-6}$/day | 1 x $10^{-6}$/day |
| Functions | TM, Ranging DCP, VHRR | TV, Radio network & Communications | TV, Radio ne work & Communications. |

tape products are generated for Landsat MSS and 70 mm quick-look for Landsat RBV and AVHRR meteorological satellites.

## 4. FUTURE PLANS

Satellite ground support facilities in India are poised for significant growth throughout the 1980's, in accordance with the aforementioned profile of the space programs. The major thrust will be in the following areas:

- Phased transfer to S-band T. T.& C.
- Augmentation of the network to cater to the needs of several simultaneous near-earth missions and launch vehicle support.
- Upgrading the tracking facilities.
- Establishment of facilities for remote sensing missions.
- Standardization of mission and network procedures to obtain compatibility with other space agencies facilitating networking, increased automation in spacecraft control, and consolidation of multi-mission service capabilities of the network.

### (a) S-band Conversion

ISRO has initiated action for the phased switch-over of all satellite T. T. & C. to S-band, with a complementary plan for S-band TTC in future Indian satellites. The first operational test is likely to be in 1982; the ASLV, PSLV and IRS missions will carry S-band TTC packages. The ISRO TTC network will continue the VHF facilities for the next few years to serve the present series of satellites over their lifetime and to provide the VHF backup systems in the qualification period of the S-band spacecraft TTC.

Fig. 8: SHAR T. T. & C. Station

Development of S-band hardware has already been initiated and at the end of 1981 a 9.1-m S-band station with TM receive-only capability was implemented at SHAR ground station. The transmit capability for telecommand and ranging is expected to be incorporated in the middle of 1982.

At Carnicobar, an S-band receiving station is already operational and the addition of data receiving capability will be available by mid-1982. At Ahmedabad, an S-band station for reception of meteorological data has already been installed, although it may soon be suitably updated for TTC operations.

Provision of S-band capability at other stations will be considered in a phased manner. All new stations are basically planned with S-band capability. Typical specifications for the S-band system for TTC operations are given in Table 6.

### (b) Augmentation of the Network

The peak loading of the ISRO network is expected to occur during the mid-1980'~~ when as many as six simultaneous missions may be supported by the network. A proposal has been made to set up a network of three ground stations in order to provide better coverage for telemetry, data reception, and tracking of near earth satellites (in the 300-500 KM altitude range). Figure 9 shows the typical coverage of the Indian subcontinent for near-earth scientific and remote sensing missions obtained by the use of the 3-station configuration.

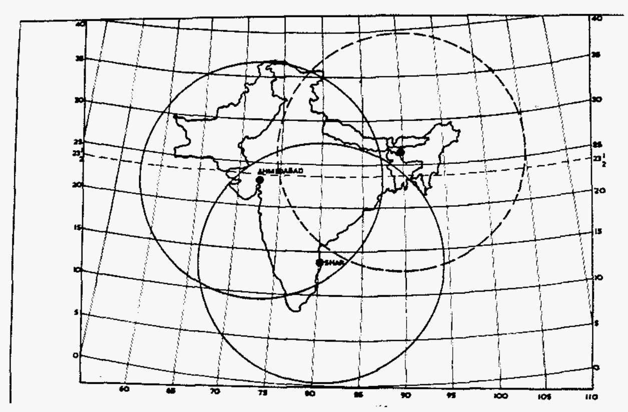

Fig 9: Coverage of the ISTRAC Network for Near Earth Satellites

The ASLV & PSLV missions would require downrange telemetry and tracking support both for tracking the vehicle's upper stage and for monitoring the spacecraft. The downrange stations must be located either on foreign territory or aboard ship. These requirements will be met by a trailer-borne transportable

TABLE 6

Typical Specifications for S-band TTC System

| Parameter | | Specifications |
|---|---|---|
| Frequency band of operation | | |
| - Uplink | : | 2025 - 2110 MHz |
| - Down Link | : | 2200 - 2290 MHz |
| Transponder type | : | PLL unified s-band turn around ratio 240:221. |
| T M System: | | |
| Modulation | : | PCM/FM/PM |
| PCM Signal | : | Bi Ø (L) |
| Bit rate | : | Upto 5 K bps |
| Sub-carrier | : | IRIG |
| T C System: | | |
| Modulation | : | PCM/FSK/PM |
| Bit rate | : | 100 bps typical |
| Sub carrier | : | TBD |
| Ground Station | | |
| Antenna size | : | typical, 9.1 m, 6.3 m |
| tracking rates | : | 9°/sec, 9°/sec$^2$ |
| Pointing accuracy | : | 0.1° |
| Receiver noise figure | : | 2 dB, 90°K |
| IF bandwidth | : | Selectable, 10 KHz - 5 MHz |
| Transmitter power | : | Variable 100 W to 2 KW |
| Search capability | : | ± 100 KHz |
| Range and range rate system | | |
| type | : | Side tone ranging and non-destructive doppler |
| accuracy | : | range 10m, range 0,1 m/sec |
| Max. range | : | 40,000 KM |
| S/N for highest tone | : | 30 dBHz |
| Magnetic recorder | : | Wideband 2 M bps 8 channel |
| PCM System | : | Microprocessor controlled display 10Hz to 1 M bps. |
| Timing system | : | Accuracy 1 m sec. |
| UT reference | : | standard time transmission. |

**TABLE 7**

**Preliminary Specifications for Shipborne and Transportable TTC Terminal**

| Parameters | Shipborne terminal | Transportable terminal |
|---|---|---|
| Frequency bar,< of operation | S band | S-band |
| Antenna | 6.3 m Cassegrain | 6.3 m Cassegrain |
| G/T | 21 dB/°K | 22 dB/°K |
| Coverage Az | ±270° | ±270° |
| El. | 0 to 90° | 0 to 90° |
| Max. tracking velocity | 9°/sec | 9°/sec |
| Acceleration | $9°/sec^2$ | $9°/sec^2$ |
| Overall pointing accuracy | 0.2° | 0.1° |
| Tracking modes | auto, manual, program | auto, manual, program |
| E I R P | 74 dBw | 74 dBw |
| Stabilisation | | |
| Pitch | ±7.5 deg | |
| Roll | ±30 deg | |
| Yaw | ±4 deg | |
| Turning rate | 6°/sec | |
| I F | 70 MHz | 70 MHz |
| Modulation | PM | PM |
| Tracking system | Tone range, doppler angle | Tone range, doppler angle |
| Accuracy Range | 10m | 10m |
| Accuracy range rate | 0.1 m / sec | 0.1 m /sec |
| Accuracy angle | 0.2 deg | 0.1 deg. |

downrange station located on land or a shipborne TTC terminal. Table 7 provides the preliminary specification proposed for these terminals.

To provide for the needs of the IRS mission, a data acquisition and processing facility will be set up to meet the special requirements of operational remote sensing missions in terms of data volume and throughput. The ground facilities will be configured so as to use the remote sensing data transmitted by LANDSAT satellites. Coverage of the entire Indian subcontinent is likely to be achieved with the help of a single station, which would reduce the overhead on the data transfer for processing. Table 8 provides a summary of the likely characteristics of the proposed IRS data receiving station.

(c) Improvements to the Tracking Systems

The tracking data for ISRO satellites include the tone range and doppler (range rate) information obtained by carrying out range measurements with the satellites and by measuring the carrier doppler shift during the satellite pass over the tracking station. The systems currently employed for SEO and RS satellites and planned for APPLE have limited system accuracies, on the order of 150 m in range and 7 m/sec in range rate; Operation in VHF band results in rather poor overall accuracies. For the remote sensing missions, where accurate subsatellite point determination is required, and for accurate target designation for S-band antennas with narrow beam widths, the accuracies will be improved by one order of magnitude; the proposed system accuracies are 10 m in range and 0.1 m/sec in range rate. The implementation of the S-band system for TTC operations, which employs auto-tracking and angle measurements to an accuracy of the order of 0.1°, has also been proposed to supplement the range and range rate data.

(d) Standardization of Missions and Network Procedures

In order to facilitate cooperation with external space agencies, mission and network procedures will conform to similar procedures adopted by those aqencies. The ISTRAC Mission-Control Centre will be expanded to handle a multiplicity of missions through the augmentation of displays and control rooms, an increase in computing power, and provision of communications network providing data links of 2400/4800 band capability. Efforts have been made to provide modular software for a variety of missions, to reduce mission-specific hardware and software to the minimum, and to provide for increased automation in spacecraft and network operations. ISTRAC hopes these will provide a viable ground support system which will cater to the needs of the Indian Space Programme in the 1980's.

TABLE 8

Typical Specification for IRS Data Receiving Station

| Parameter | Specifications |
|---|---|
| Frequency band | X 3and |
| Antenna - type | 9.1 m Cassegrain |
| - Coverage | Az ±270 deg. |
| | El. 0 to 90 deg. |
| Tracking rate - Velocity | 20°/sec |
| - Acceleration | $20°/sec^2$ |
| Antenna pointing accuracy | C.01 deg. |
| Receiver noise temp. | 120°K |
| IF | 400 - 500 MHz & 70 MHz |
| Demodulator type | QPSK |
| C/N for $1 \times 10^{-5}$ BER | 12 dB |
| Sit synchroniser -bit rate | as required (25 M bits,- 84M b. |
| Recorder type | HDDT |
| No.of channels | 12 to 24 |
| Bit rate | 4 M bits/channel. |